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The Economic Importance of the Mediterranean Fruit Fly to Hawaiian Horticulture

BY ARTHUR C. MASON
Bureau of Entomology, U. S. Department of Agriculture
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The Mediterranean fruit fly (*Ceratitis capitata* Wied.) has been the subject of much discussion in recent literature, both as to its possible distribution in nature and as to its potential economic effect on horticulture. The insect has proved to be a destructive pest in every country where it has become established. In the Hawaiian Islands an almost ideal environment for the fly exists, since the temperature and humidity ranges during a great part of the year are within the optimum limits for its development and, in addition, a continuous succession of host fruits is available. These facts, coupled with the enormous fecundity of the insect, have caused its rapid increase and dissemination over the Islands, resulting in considerable damage to horticultural crops. However, after a period of more than 20 years under conditions brought about by the Mediterranean fruit fly, a substantial basis for horticulture still remains, and many fruits and vegetables are produced for local consumption.

Generally considered to be dependent on outside sources of supply for fresh produce, the Islands are largely self-supporting in this respect. Although considerable quantities of fruits and vegetables are imported for local use, this produce is of the varieties which do not grow well here because of climatic conditions or because they can be grown to better advantage elsewhere.* Hawaii not only produces large quantities of fruits and vegetables for home consumption, but could doubtless raise additional supplies for export if there were no quarantine restrictions. During the year of the fruit-fly outbreak in Florida, the Bureau of Entomology laboratory in Hawaii had an unusually large number of

* In the case of tomatoes and possibly some other fruits, insects other than the fruit fly limit their production locally.

visitors seeking information about the fly. Among these were people vitally interested in fruit growing in the States. Almost without exception these people expressed surprise at the quantity and variety of fruits grown here.

The present condition of horticulture in Hawaii, however, is no justification for the existence of the fruit fly, either here or elsewhere. It is generally agreed that absolute freedom from the pest would produce a much happier state of affairs. Neither is it an argument against the existing quarantines. The writer firmly believes that there should be no relaxation in present quarantines, and that every effort should be made to limit the distribution or spread of the fly. The pest has possibilities for great damage to horticulture in some sections of the United States. The methods by which Florida achieved apparent success in eliminating the insect from the State are hardly applicable to Hawaii at present. Nevertheless, all effort should be expended not only for better control, but looking toward the ultimate elimination of the insect from Hawaii.

HISTORY OF THE PEST IN HAWAII

An extended study of the Mediterranean fruit fly in Hawaii has been conducted by the Bureau of Entomology almost from the time the insect became established here. First found in Honolulu, in 1910, its dissemination was rather rapid, until by 1914 it had spread to all the islands of the group. Nearly ten years were required, however, for it to reach its maximum distribution and population, as is shown by yearly records of infestation started by the bureau in 1912 and continued up to the present. Willard and Bissell (8) show that the average number of larvae per fruit during the period 1916-1924 reached its maximum point in 1917 and 1918. It is interesting to note that the introduced parasites also reached their maximum, both in numbers and in efficiency of control, at about the same time.

In 1913 and 1914 the Territory successfully introduced four parasites: *Opius humilis* Silv., *Diachasma tryoni* Cam., *Diachasma fullawayi* Silv., and *Tetrastichus giffardianus* Silv., which have been of material assistance in reducing the population of the flies. These parasites have spread throughout the range of the fruit fly

and have adapted themselves to their new environment. Parasitism of the fruit-fly larvae increased yearly until 1918, when, as shown by Willard (6), a total parasitism of about 50 per cent was attained for all larvae examined. Yearly records made since then indicate little, if any increase in efficiency of the parasites. Results as shown by Willard and Bissell (8) for the years between 1916 and 1924, as well as later manuscript reports by Willard and Mason, show that the average yearly percentage of parasitism remains around 50 per cent. A fairly constant relationship between the parasites and the fruit fly has been maintained. Although an average of approximately half of the larvae are destroyed by the parasites, the amount of infestation has remained more or less stable.

EXPERIMENTAL PROCEDURE

The study of the economic effect of the Mediterranean fruit fly on horticultural crops described herein was therefore made under conditions of parasitism as outlined, and which are considered as fairly stable and continuing. Records of infestation in many of the host fruits of the fly are presented, and the relation of its injury to Hawaiian horticulture is shown. These fruits will be discussed in the order of their economic value to the islands. Unless otherwise stated, all the records were made from tree-ripened fruits. The samples of fruits were picked from the trees when they had reached a mature or edible condition. They were then taken to the insectary and placed on an inch or two of dry, clean sand in individual containers. Here they were kept, usually for 20 days. At the end of each five-day period the sand was sifted, the larvae and pupae were removed and counted, and a record was made of the number obtained. After four such siftings the total infestation for each fruit was determined. Whenever it was possible, samples were taken from several different localities in order to have representative collections.

PINEAPPLES

The pineapple (*Ananas sativus*) naturally comes first in this discussion, since pineapple growing ranks second only to sugar among Hawaiian industries. It is well known that pineapples are free from any damage by *Ceratitis capitata*. No instances are on

record in Hawaii of a pineapple being infested by this insect. Repeated attempts, as reported by Back and Pemberton (3), to rear the fruit-fly larvae under forced conditions in ripe pineapples have always failed, although these authors refer to attack on pineapples in the Fiji Islands by the pineapple fruit fly (*Dacus xanthodes* Broun) and the Queensland fruit fly (*Dacus tryoni* Frogg.), neither of which occurs in Hawaii. There are no restrictions on the exportation of this fruit.

COFFEE

Second in order of horticultural value and fifth among Hawaiian industries is the coffee crop. From the beginning of fruit-fly infestation in the Islands, coffee (*Coffea arabica*) has served as an important host of the fly. Infestation in the coffee fields rapidly increased from the start in 1912, and soon reached the point where about 90 per cent of the cherries were infested. Although it was recognized from the beginning that the larvae were in no way injuring the coffee seeds, their presence in the surrounding pulp reduced the weight of the cherries and thus disturbed the system of picking and marketing then in use, and also caused dropping of the cherries, due to fungous diseases and fermentation.

The introduction of the opiine parasites solved these difficulties at once. These parasites were liberated in the Kona coffee fields in 1914-15, and found conditions ideal for their development. The coffee cherry being a small fruit with thin flesh, the parasites could readily reach the fly larvae and oviposit in them, and there was a rapid increase in parasitism and consequent decline in fly population. This rapid reduction of fruit-fly population in the coffee fields has often been cited as an outstanding instance of parasite control. Willard (7) states that the average number of larvae per thousand coffee cherries obtained in 1917 was 765, 42 in 1923, 33 in 1924, and 19 in 1926. Some recent records of infestation in individual coffee cherries show an average of 2.1 larvae per infested fruit. On this basis the actual number of coffee cherries infested in the Kona coffee fields is less than 10 per thousand. Damage by the fruit fly has not for several years been considered a factor in coffee growing.

BANANAS

Bananas of the Chinese (*Musa cavendishii*) and Bluefield (*Musa sapientum*) types are the only other Hawaiian fruits grown for export, as well as for home use. These fruits are permitted to enter the States upon certification as to their condition of nonmaturity at the time of packing for shipment. The fruit fly has never been found infesting bananas of these types growing under natural conditions in Hawaii.

Back and Pemberton (2) report that a careful examination made of more than 30,000 fruits ready for shipment did not show a single egg puncture; also that 1,014 prematurely ripened fruits cut from bunches in the field and held in rearing jars in the insectary did not produce a single larva. Fly-traps maintained in the fields while the fruits were growing showed an abundant fly population.

Although infestation in ripe bananas on the tree can be produced under forced conditions, such is not true of green bananas on the tree, owing largely to the exudation of the tannin-laden sap which prevents the female from ovipositing. Hence, as a precautionary measure, green fruits only are permitted for export, all prematurely ripened and cracked fruits being removed from the bunches before they are wrapped. The common horticultural practice is to pick bananas while they are still hard and green so that even if the fly did attack the ripe fruits in the field, this would not be a factor in their production either for home use or for export. In his bulletin on banana culture in Hawaii (4) Pope states that "no evidence has been obtained indicating that commercial varieties are susceptible to attack by the pest. This fact has failed to receive the publicity to which the banana industry is justly entitled." This applies to the types named at the opening of this paragraph.

In the case of cooking bananas, there are a few instances on record of infestation to fruits growing under natural conditions. Back and Pemberton (2) report a single instance each of infestation in Popoulu and Moa varieties (*Musa* spp.). Willard, in an unpublished manuscript on the susceptibility of cooking bananas to attack by the fruit fly, reports that he examined 8,296

fruits of Maiamaoli bananas from Honolulu markets and found 13 of them to have egg punctures, a few of which contained dead eggs or dead young larvae. Similarly, an examination of 200 fruits of the Popoulu cooking bananas showed egg punctures in 5 fruits, from one of which 10 adult flies were reared. Cage experiments demonstrated that it was possible for adult flies to oviposit in green cooking bananas on the trees, but no adults could be reared. Only in ripe or cut green bananas was it possible to rear the flies to maturity. The few known cases of infestation in cooking bananas make it unwise to allow them to enter the States, but does not limit the production and consumption of these bananas locally.

AVOCADOS

Avocado growing has great possibilities in Hawaii, especially since the Guatemalan types have been introduced and found to meet with favor. Local markets are well supplied with these fruits throughout the greater part of the year, and only the quarantine laws prevent the development of a large industry for export purposes. It has been demonstrated that all types of the avocado (*Persea gratissima*) are possible carriers of the fruit fly, although the infestation is so slight that it is not considered in raising fruits for local use.

Figures published by Willard and Mason (9) from extensive work with Guatemalan avocados between 1925 and 1929 show that, of 1,269 fruits, representing 12 varieties grown under natural orchard conditions, only 5 fruits were infested. This represents less than four-tenths of 1 per cent of the entire lot. When adult flies were caged about the fruits on the trees for 24 hours, 1.3 per cent of 231 fruits became infested. Even when held under forced conditions in jars in the insectary, 826 fruits had infestation in only 18, or 2.2 per cent of the total number. These figures indicate that the fruit fly is a negligible factor in the production of Guatemalan avocados for local use.

The so-called summer avocados of the West Indian race are sometimes attacked more severely by the fruit fly. Even here infestation is, in the main, limited to a few trees where the fruits perhaps lack the qualities of resistance shown by most varieties.

Two hundred summer pears collected in the vicinity of Honolulu and held in the insectary for individual infestation records gave an average infestation of 4 per cent. All the infested fruits of this group came from the same tree in Manoa; five collections from other trees had no infestation. Seventy-one fruits of the Wishard variety, recently received from Haiku, Maui, had an average infestation of 25.3 per cent, while samples of several other varieties from the same orchard collected about the same time had no infestation. A tree growing in the writer's dooryard has produced several hundred high-quality fruits during the past two years and only two infested fruits have been noted.

Certainly the fruit fly receives little consideration in raising avocados for home and market use in Hawaii. Elimination of the occasionally infested tree or the varieties most susceptible to attack would almost entirely remove the fruit-fly problem from avocado growing. Even the common practice of picking avocados while they are hard, in order to facilitate handling and insure their reaching the consumer in good condition, eliminates most of the chance of infestation.

PAPAYAS

The papaya (*Carica papaya*) is an important commercial crop in Hawaii and a regular article of diet in most homes. Fruit-fly infestation in these fruits is so rare that they are not even considered by most people to be a host. The writer has never seen a papaya on the market which showed the presence of maggots. The usual commercial practice of picking papayas while they are still firm and just starting to show the ripening color removes practically all chances of infestation, since the female fly seldom, if ever, oviposits in a green papaya, as the exudation of the milky acrid juice which occurs as soon as the fruit is punctured prevents the fly from inserting her ova. In addition, experiments have shown that the young larvae are unable to live in the green fruits. If the fruits are allowed to remain on the trees until they are very soft and ripe, infestation often takes place. Of 171 such fruits, picked from the trees after becoming very soft and in most cases overripe, 23.4 per cent showed infestation. Inasmuch as papayas picked while they are still firm are considered preferable to tree-ripened fruits for culinary pur-

poses, the fruit fly can not be considered a factor in limiting their production. The fruits are, at present, so abundant that they are often used for chicken feed and hog feed.

MANGOES

The mango (*Mangifera indica*) is one of the most favored hosts of the fruit fly and perhaps its main supporting host during the summer season. Still, several of the finest varieties of mangoes in Hawaii are almost free from attack, even when growing in an environment of concentrated fly population. The common seedling mangoes, however, are so badly attacked that the crops are considered of little or no value. Infestation in certain samples of these fruits has reached 100 per cent. A comparative study made during the past two years of the infestation in several varieties of mangoes shows the average infestation to range from zero up to 58.8 per cent. In Table 1 the varieties of mangoes studied are listed in the order of their freedom from attack; and the number of fruits examined, the number infested, and the percentage of infestation are shown.

TABLE 1.—FRUIT-FLY INFESTATION IN MANGOES

Variety	Number examined	Number infested	Per cent infestation
Bierbach	18	0	0
Victoria	182	2	1.1
Pirie	121	2	1.6
Smith-Wootten	150	3	2.0
Cowasjee-Patel	37	1	2.7
Whitney	113	4	3.5
No. 9	112	5	4.4
Mullgoa	38	2	5.3
Ehrhorn	214	12	5.6
No. 5	43	3	7.0
Scott-Pirie	53	4	7.5
Wootten	144	11	7.6
Holt	63	5	8.0
Manila	100	14	14.0
Chinese	25	6	24.0
Hawaiian	643	227	35.3
French	85	50	58.8

It is seen that less than 5 per cent infestation was found in several of the best varieties of mangoes growing here. In the case of the Hawaiian mangoes infestation averaged 35.3 per cent in 643 fruits collected from several localities about Honolulu; in French mangoes it reached an average of 58.8 per cent. When it is known that most of the better varieties of mangoes examined came from trees in the experimental orchards of the Hawaii Experiment Station, in close proximity to other heavily infested host fruits, and also that flytraps maintained in the trees themselves showed large numbers of flies present during the ripening season, it will be realized that these fruits have considerable resistance to attack. The results prove, therefore, that it is possible to grow good mangoes in Hawaii in spite of the fruit fly. Pope (5) lists eight varieties as being immune or nearly free from attack. Recently some new seedling varieties have been developed with fruits of exceptional quality, color, and size, and which as yet have shown no evidence of fruit-fly injury. These facts all tend to substantiate a belief, long held by the writer, that elimination of the undesirable Hawaiian mangoes either by top-working over the trees or replacing them entirely with trees of the better varieties not only would result in the production of a superior crop of mangoes remarkably free from infestation, but also would materially reduce the fruit-fly population of the Islands by removing its main supporting summer host in the lowlands of Hawaii.

GUAVAS

The guava (*Psidium guayava*) is another of the chief supporting hosts of the fruit fly in Hawaii. Growing over a large area of the wild and mountainous portions of the Islands and extending up to the limits of range of the fly, the trees provide an almost constant supply of host fruits. The fruits are universally infested, although at the lower elevations (up to 500 feet) the average infestation and the average number of larvae per fruit are greater than at the higher elevations. In 1,485 fruits representing collections from many localities and from sea level up to 2,000 feet, the average infestation was 61.6 per cent, with an average of 10.9 larvae per infested fruit.

In making these infestation records it was found that only 3.4 per cent of the larvae emerged from the fruits during the first five days of holding, and that 45.2 per cent emerged after the tenth day. As in the case of most other fruits studied, the guavas were picked from the trees when ripe and yellow and in an edible condition, at which time, the records indicate, the insects are in the egg or first larval stage. Since fruits for processing are desired at this same stage of maturity, and are used before any decay resulting from infestation has set in, the presence of the insects does not interfere with their use or depreciate their value. Normally the fruits have fallen from the trees and are well decomposd before the larvae leave them.

Although not cultivated as a horticultural crop, the guava fruits have some commercial value in the making of jam, jellies, ice cream, etc. For these purposes, as previously explained, the infestation by the fly can not be said to lessen the value of the fruits.

Infestation of the guava fruits by the fly has apparently had no effect on the rapid spread and dissemination of the host trees over the Islands.

CITRUS FRUITS

The effect of the presence of the fruit fly in Hawaii on citrus growing is difficult to estimate, owing to the scarcity of citrus fruits for study, and especially to the absence of large plantings. Orange trees were grown more generally in the early days, and at one time oranges were exported to California, but this practice was discontinued long before the advent of the fruit fly in Hawaii. Practically all the citrus fruits consumed locally are now imported from California; so, while the fruit fly undoubtedly exerts a limiting influence on dooryard production of oranges, it is not believed that its presence affects the commercial production to a very great extent.

Some records were made in 1929-30 on oranges (*Citrus sinensis*) obtained from a planting in Kona, Hawaii. This grove, composed of about 350 sweet seedling trees, is probably the largest single planting in the Islands. From 638 fruits picked from these trees at several times during the season and held over sand in the insectary, a total of 122 larvae were obtained. Unfortunately, in-

dividual records on the fruits were not made. However, assuming 6 larvae per infested fruit, which is a conservative estimate, there were about 20 infested fruit—an infestation of about 3.2 per cent of the entire lot.

Practically all of these larvae were obtained from fruits picked in late December and January. The owner of the grove attempts to market all the fruits before Christmas, and stated that he had little trouble from fly infestation unless the fruits remained on the trees after the first of January. Back and Pemberton (1) reached a similar conclusion from their study of the susceptibility of citrus fruits to attack by the Mediterranean fruit fly. They state: "While grapefruit, oranges, lemons, and many limes may become quite badly infested with well-grown larvae if allowed to remain on the tree long after they become sufficiently ripe for the market, nature has so well equipped them to withstand attack that larvae are seldom found in their pulp until they are much overripe."

The thin-skinned oranges of the satsuma and tangerine types (*Citrus nobilis*) are much more seriously attacked. Samples taken from the small satsuma grove in Kalihi Valley, and consisting of 75 fruits which were unprotected and had ripened on the trees, had an infestation of 33 per cent. The owner of this grove finds it necessary to protect all the fruits on the trees with paper sacks in order to insure freedom from attack by the flies so that he can produce a marketable crop. In the case of the tangerines a single sample of 25 fruits had an infestation of 16 per cent. Similarly, 75 scented oranges from the experiment station orchard averaged 25.3 per cent infestation.

Lemons (*Citrus limonia*) are practically immune to damage by the fruit fly. Fifty-five Villa Franca lemons and 75 seedling lemons failed to show any infestation. Back and Pemberton (3) also state that they have never seen an infested lemon that had not been mechanically injured. Limes suffer slightly when allowed to remain on the trees until very ripe; 375 such fruits of the Kusaie lime (*Citrus aurantifolia*) were infested to the extent of 8.8 per cent. In the case of the grapefruit (*Citrus grandis*) infestation is also found in overripe fruits; 150 Whitney pomelos averaged 8.7 per cent infestation. However, all the infested

fruits were found late in the season and those picked shortly after they had reached maturity were free from attack. The sour orange (*Citrus aurantium amara*) is probably the most favored host among the citrus fruits, 76 per cent of 100 fruits having been found infested with an average of 31.5 larvae per fruit. The calamondin or Chinese orange (*Citrus japonica*), a tree grown mostly for ornamental purposes, is also a favored host, 409 of the fruits collected from several of these trees showing an average infestation of 59.2 per cent.

Most of the citrus fruits from which records were made were obtained from the Hawaii Experiment Station orchard, where they were exposed to heavy attack due to continuity of hosts and to the fact that many of the fruits remain on the trees until overripe and often until they drop.

FRUITS OF LESSER COMMERCIAL VALUE

Grapes of the Isabella variety (*Vitis labrusca*) are grown to a limited extent for local markets and home use. In 150 bunches of these grapes, representing six collections, no larvae were found when the grapes were held over sand in the insectary. Neither have any instances of field infestation in Island grapes ever been noted by the writer. Back and Pemberton (3) mention a single case of infestation found in locally grown grapes. In an effort to obtain infested grapes for experimental use, oviposition was accomplished only under forced conditions in the insectary. Later examination of these grapes showed only 133 larvae and 652 dead eggs, indicating that more than 83 per cent of the eggs failed to hatch in the grapes.

The fig (*Ficus carica*) is a favored host of the fruit fly and the fruits are often heavily infested if left on the tree until they are very soft and ripe. The milky acrid juice of the green figs, however, generally prevents oviposition by the flies. One hundred tree-ripened figs held over sand yielded a total of 342 larvae from 36 of the fruits. Only 22 per cent of the larvae emerged during the first five days of holding, however, indicating that the larvae were very small at the time the fruits were picked. The common practice of picking figs while still firm in order to facilitate market handling usually removes them from the tree before they are subject to infestation. On the other hand, on dooryard trees

bagging of the fruits is sometimes resorted to. Many lots of ripe figs purchased in the market for home use have failed to show any decay due to infestation. Complete immunity to fly attack on one variety is claimed by the grower of these figs.

The breadfruit (*Artocarpus incisa*), although listed by Back and Pemberton (3) as a host, is probably never infested. These authors state that there are no definite records of infestation available. Forty-four recently fallen and overripe fruits held in the insectary failed to produce a single larva, and no instance of infestation has been called to the writer's attention.

In the case of the mangosteen (*Garcinia mangostana*) only 1 of 75 fruits examined, or 1.33 per cent, was found to be infested.

The loquat (*Eriobotrya japonica*) is one of the favored hosts of the fruit fly. In 300 fruits, representing 12 collections, there was an infestation of 80 per cent, with an average of 8.7 larvae per infested fruit. Successful production of loquats under present Island conditions requires bagging of the fruits, but these fruits have little commercial value.

Sapodillas (*Achras sapota*) are also heavily infested when grown unprotected. A small sample of fruits held in the insectary had an infestation of 62.5 per cent. Only an occasional tree of this species grows in the Islands and the fruits are in little demand.

The strawberry guava (*Psidium cattleianum*) is severely attacked by the fruit fly when allowed to mature on the trees, 250 fruits having an average infestation of 72.8 per cent. As in the case of the regular guavas and figs, however, oviposition rarely takes place until the fruits are very soft and ripe. Only a small percentage of the larvae in the samples of tree-ripened fruits under observation emerged during the first five days of holding. Since the chief use of the strawberry guava is for cooking and jelly making, the presence of the insects in the egg and early larval stages can not be said to depreciate their value very much.

Two samples of mountain apples (*Jambosa malaccensis*), taken at the lower altitudes of its range and near cultivated host fruits of the fly, were infested to the extent of 58 per cent. Usually growing wild well up in the mountain forests, the fruits of this tree are ordinarily free from infestation, and good fruits are commonly offered for sale during the season.

FRUITS OF DOUBTFUL COMMERCIAL VALUE

Another group of fruits, although of rather doubtful commercial value, will be considered here since it contains some important hosts of the fruit fly. This group contains the star apple (*Chrysophyllum cainito*), rose apple (*Eugenia jambos*), French cherry (*Eugenia uniflora*), white sapota (*Casimiroa edulis*), carambola (*Averrhoa carambola*), and Natal plum (*Carissa arduina*). These fruits are grown to a limited extent in home gardens either for food value or ornamental purposes.

Infestation records as determined for these fruits are given as follows: 235 star apples, representing 10 collections of fruits, had an average infestation of 50.2 per cent; in 400 rose apples there was an average of 76 per cent attacked, two of the samples of 25 fruits each showing 100 per cent infestation; 19 collections of French cherries, representing a total of 475 fruits, varied in degree of infestation from 8 to 100 per cent, with an average of 53 per cent; 3 small samples of white sapotas, representing 33 fruits, were 100 per cent infested in each case; 5 lots of carambolas, with a total of 122 fruits, contained 3 infested fruits, or an average infestation of 2.4 per cent; Natal plums were 14 per cent infested in 4 collections, representing 100 fruits.

VEGETABLES

This discussion will not be complete without considering some of the vegetable crops which are purported to be hosts of the fruit fly. In this connection the attack of the fruit fly must not be confused with the damage caused by the melon fly (*Bactrocera cucurbitae* (*Coq.*)), a related insect which is primarily an enemy of certain vegetable crops.

The tomato (*Lycopersicum esculentum*), although commonly considered as a host, has never been found to be attacked. From 648 fruits, representing 25 different collections, no larvae were obtained when the fruits were held in the insectary. Neither are any authentic records available of fruit flies having been reared from tomatoes grown under natural field conditions. Tomatoes have often been infested artificially and the larvae reared through in them, but they are not attacked in the field. Although listing tomatoes as a host of the fruit fly, Back and Pemberton (3) have not recorded any instances of natural infestation.

Eggplants (*Solanum melongena*) are also listed by Back and

Pemberton (3) as hosts, but their records show only one infested fruit from 1,115 examined, or less than one-tenth of 1 per cent. In an effort to obtain infested eggplants for experimental use, 132 fruits were placed in jars containing adult flies and held in the insectary. Even under such forced conditions, infestation was obtained in only 3 of these fruits. Hence it appears that eggplants are most improbable hosts of the fruit fly.

Onions are sometimes considered as possible carriers of the fruit fly. Work conducted a few years ago by H. F. Willard, and reported in manuscript only, shows that the fruit fly could not be reared through in onions of the Australian brown and Spanish types. Although adult flies would deposit eggs in the onions under forced conditions, none of them were able to develop. No instances are on record of infestation in onions in Hawaii. The same is true of beans of all types, although broadbeans have been reported (in correspondence) as a host in Bermuda.

Melons of all kinds are severely infested by the melon fly, but not by the fruit fly. Although fruit flies have often been reared from melons infested in the insectary, no records are obtainable of infestation under field conditions.

The green pepper (*Capsicum annuum*) is the only vegetable in which natural infestation by the fruit fly has been found. Among 197 green peppers purchased in the local markets, 19 infested fruits were found, or an average of 9.6 per cent infestation, and with an average of 5.2 larvae per infested fruit. Another lot of several sacks of green peppers was purchased for cold-storage experiments, and from 150 fruits selected from the lot as checks to determine the larval population, 66 larvae were obtained. Figuring the individual infestation on the average of 5.2 larvae per fruit as given above, about 12 fruits, or an average of 8 per cent of the lot, were infested. This figure is comparable with that of the first lot, and shows that green peppers average about 9 per cent infestation. As in the case of some previously mentioned fruits, only about 25 per cent of the larvae emerged during the first five days of holding. Hence, it will be seen that little decay or loss results from fruit-fly infestation in peppers.

CONCLUSION

Infestation records are included on all the important supporting hosts of the Mediterranean fruit fly, and the injury to such

hosts is indicated. These records show that Hawaii is able to grow an abundant crop of fruits and vegetables for home use, and in some cases for export, with little loss caused by the fly. Although severe infestation does take place in some varieties of citrus fruits and mangoes, in peaches, guavas, figs, and some of the minor fruits, including both edible fruits and fruits of ornamental plants and trees, some of these host fruits are not of commercial value, or can be picked before infestation occurs or used in ways to overcome the factor of infestation. The green pepper is the only vegetable crop whose production is affected by fruitfly infestation. Among the fruit crops the production of pineapples, bananas, avocados, papayas, some kinds of citrus fruits and mangoes, grapes, breadfruit, mangosteens, and some other lesser important fruits is scarcely, if at all, limited by the presence of the fly. Strawberries, mulberries, pohas, and some of the other minor fruits are not classed as hosts.

The growing of more resistant varieties of some of the favored hosts, elimination of nonessential host fruits, and a program of control through orchard and dooryard sanitation, together with the use of poison bait spray, would probably result in largely removing the insect from the lowlands of Hawaii.

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